OPEN FUGITIVE DUST -

PM10 SOURCES AND CONTROLS

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PURPOSE

To provide regulatory personnel with sufficient information to develop control plans for open dust sources of PM10 impacting on urban areas.

OPEN FUGITIVE DUST
PM10 WORKBOOK

Table of Contents

SOURCE AND EMISSION CHARACTERIZATION

FUGITIVE PARTICULATE EMISSIONS

PROCESS SOURCES

Associated with industrial operations that alter the chemical or physical characteristics of a feed material.

OPEN DUST SOURCES

Entail generation of solid particles by the forces of wind or machinery acting on exposed materials.

GENERIC CATEGORIES OF OPEN DUST SOURCES

1. Unpaved Travel Surfaces
   - Roads
   - Parking lots and staging areas
   - Storage piles

2. Paved Travel Surfaces
   - Streets and highways
   - Parking lots and staging areas

3. Exposed Areas (wind erosion)
   - Storage Piles
   - Bare ground areas

4. Materials Handling
   - Batch drop (dumping)
   - Continuous drop (conveyor transfer, stacking)
   - Pushing (dozing, grading, scraping)
   - Tilling

PM10 SOURCE CONTRIBUTIONS FOR DENVER

- PM10 is approximately 50% of TSP

- Fugitive dust sources contribute approximately 60% of PM10

Source: F. J. Huhn, 1988.

CALCULATION OF EMISSION RATE

$$R = M\ e\ (1 - c)$$

where:

R = estimated mass emission rate

M = source extent

e = uncontrolled emission factor, i.e., mass of uncontrolled emissions per unit of source extent

c = fractional efficiency of control

AP-42 EMISSION FACTORS

- Single-valued means
- Predictive equations

CORRECTION PARAMETERS FOR PREDICTIVE EQUATIONS

- Measures of source activity

- Properties of disturbed material

- Climatic parameters

EMISSION FACTOR DEVELOPMENT

Log Transformation

Regression Analysis

Cross Validation

Independent Validation

PM10 EMISSION FACTOR FOR URBAN PAVED ROADS

$$e = 2.28\ (sL/0.5)^{0.8}\ (g/VKT) \qquad (2\text{-}1)$$

$$e = 0.0081\ (sL/0.7)^{0.8}\ (lb/VMT)$$

where:

e = PM10 emission factor, in units shown above

s = surface silt content, fraction of material smaller than 75 μm in diameter

L = total surface dust loading, g/m^2 ($grains/ft^2$)

VKT = vehicle kilometers traveled

VMT = vehicle miles traveled

DUST PRODUCING MATERIALS

- Bare ground/soil
- Road and parking lot aggregate
- Storage piles
- Anti-skid material

- Tracking
- Spills

SOURCE PRIORITIZATION FACTOR

$$\frac{\text{Uncontrolled Emission Rate}}{\text{Source Surface Area}}$$

BASIC CONTROL STRATEGIES

TECHNICAL GUIDANCE DOCUMENT

Technical

- Control techniques
- Procedures for estimating effectiveness
- Estimated effectiveness
- Procedures for estimating cost and cost-effectiveness

Regulatory

Alternative regulatory formats

Procedures for enforcing

FUGITIVE EMISSIONS CONTROL STRATEGY DEVELOPMENT

- Identify/classify fugitive emission sources
- Prepare emissions inventory
- Identify control alternatives
- Estimate control efficiencies
- Calculate cost and cost effectiveness

SOURCE CATEGORIES

Paved Roadways (VMT)

- Public
- Industrial

Unpaved Roadways (VMT)

- Public
- Industrial

Storage Piles (disturbed area; quantitity transferred)

Construction/Demolitoin Activities (floor area)

Open Area Wind Erosion (exposed area)

Agricultural Tilling (tilled area)

PREVENTION

Confinement of dust producing material.

MITIGATION

Periodic removal of dust producing material.

CONTROL TECHNIQUES

1. Stabilization of Unpaved Travel Surfaces

    - Wet suppression
    - Chemical stabilization
    - Physical stabilization
    - Paving

2. Improvement of Paved Travel Surfaces

    - Surface cleaning
    - Resurfacing
    - Reduction of track-on

3. Stabilization of Piles/Exposed Areas

    - Wet suppression
    - Chemical stabilization
    - Physical stabilization

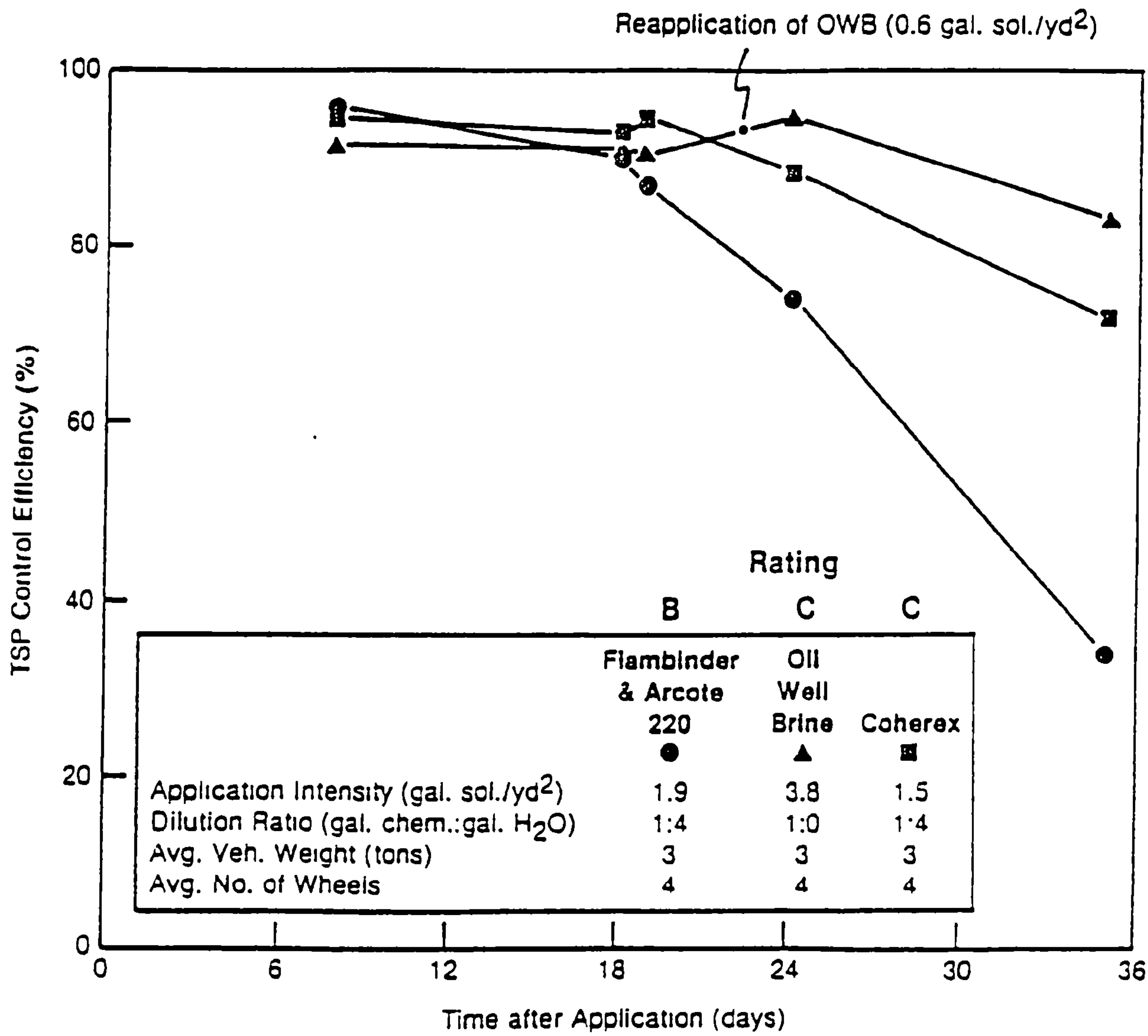
CONTROL TECHNIQUES
(Continued)

4. Enclosure of Piles/Exposed Areas or Materials Handling

   - Passive enclosures (including wind fences)
   - Active enclosures

5. Wet Suppression for Materials Handling

EXAMPLE FIELD DATA FOR CHEMICAL TREATMENT OF UNPAVED ROADS



CONTROL TECHNIQUES

Preventive Measures

- Passive enclosures
- Wet suppression
- Stabilization of unpaved surfaces
- Work practices (reduce the uncontrolled emission factor)

Mitigative Measures

- Periodic removal of exposed dust producing material
- Paved surface cleaning

CONTROL STRATEGIES BASED ON AP-42 EMISSION FACTOR EQUATIONS

Source category	Control strategies
Paved roads	Reduce source extent (traffic volume) Reduce silt loading
Unpaved Roads	Reduce source extent (traffic volume) Change traffic characteristics (vehicle speed, weight, wheels) Reduce silt content Increase surface moisture

CONTROL STRATEGIES BASED ON AP-42 EMISSION FACTOR EQUATIONS (Continued)

Source category	Control strategies
Materials transfer operations	Reduce source extent (mass transferred) Reduce wind speed Increase moisture content
Wind erosion--storage piles and open areas	Reduce source extent (exposed surface area) Reduce frequency of disturbance Reduce disturbed area Reduce wind speed Increase moisture content Increase threshold friction velocity

CONTROL PERFORMANCE CHARACTERIZATION AND REGULATORY OPTIONS

OPEN DUST CONTROL EFFICIENCY

$$\text{Control (\%)} = \frac{e_u - e_c}{e_u} \times 100\%$$

where:

e_u = uncontrolled emission factor

e_c = controlled emission factor

OPEN DUST CONTROLS

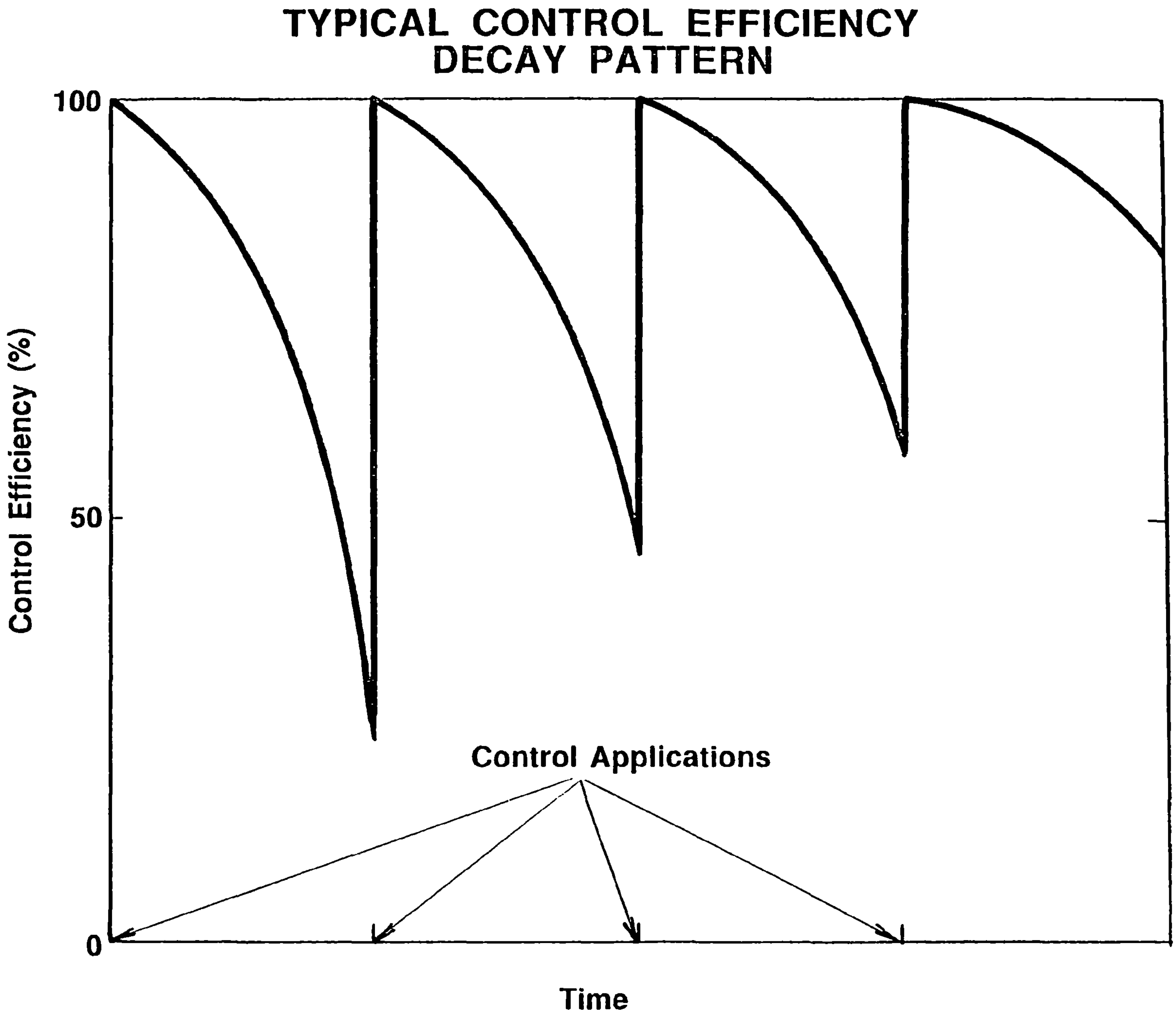
- CONTINUOUS - control functions at an essentially constant level of efficiency over time [$e_c(t) \approx$ constant] (examples - enclosures on water sprays for material handling operations, wind fences, permanent improvement of travel surfaces)

- CYCLIC - control requires reapplications to maintain an acceptable level of efficiency; effectiveness decreases over time [$e_c(t)$ an increasing function of time] (examples - water on chemical dust suppressants applied to unpaved roads).

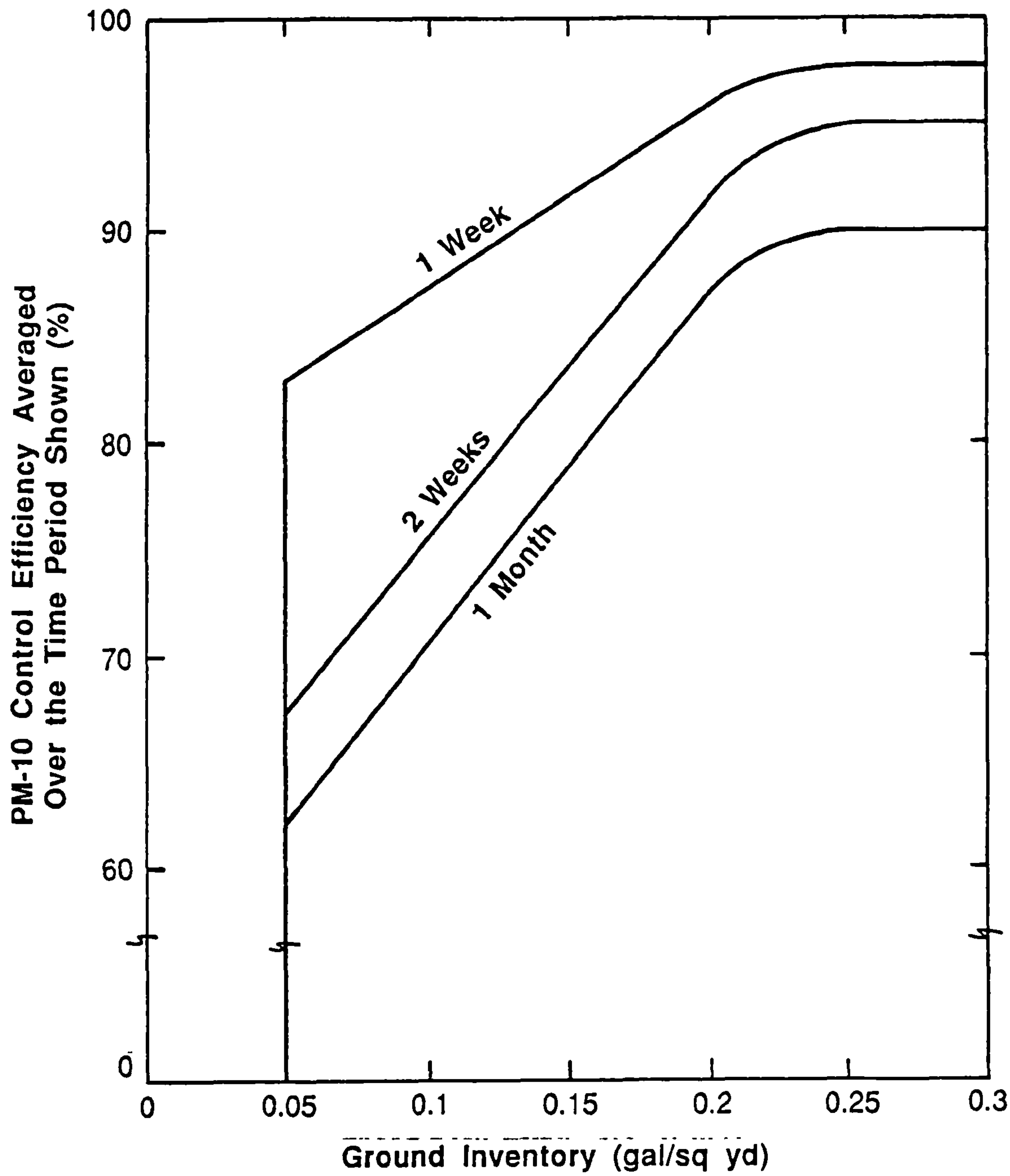
"RESIDUAL" EFFECTS OF CYCLIC OPEN DUST CONTROLS

Later applications tend to have higher efficiencies (major exception - watering of unpaved roads).

Because of the above, less intense control applications with greater time intervals between applications may be used to maintain an acceptable level.


TYPICAL CONTROL EFFICIENCY
DECAY PATTERN
100
50
0
Control Efficiency (%)
Control Applications
Time

CHEMICAL DUST SUPPRESSANT CONTROL EFFICIENCY MODEL



CYCLIC CONTROL TERMINOLOGY

INSTANTANEOUS CONTROL EFFICIENCY (ICE)

Efficiency based on controlled emissions at time "t" after application

$$\text{ICE } (\%) = \frac{e_u - e_c(t)}{e_u} \times 100\%$$

AVERAGE CONTROL EFFICIENCY (ACE)

Efficiency based on time history of ICE

NOTE: Both ICE and ACE are functions of time after application.

OVERVIEW OF REGULATORY OPTIONS

FRAMEWORK

Permit System for Industrial Sources

Use of building permits to control construction/ demolition dust and carryout to public roads

Joint Memoranda of Understanding with municipalities for public roads

Enforcement (e.g., traffic tickets) of current laws against uncovered trucks, illegal stopping on unpaved shoulders, etc.

POSSIBLE EXEMPTIONS

<u>Meteorology</u>

- When rainfall is sufficient to act as 80% + control
- Under calm wind conditions
- In winter when source material is agglomerated/compacted by freezing

<u>Special Sources</u>

- Application of salt/sand to highways
- Agricultural operations
- Roads with <100 vehicles/day (weight <3 ton)

POSSIBLE EXEMPTIONS
(Continued)

General

- Where duration of operation is <x min. per day

- Attainment areas where degradation of air quality is unlikely

REGULATORY FORMATS

- Reasonable precautions to minimize emissions

- No visible emissions beyond the property line

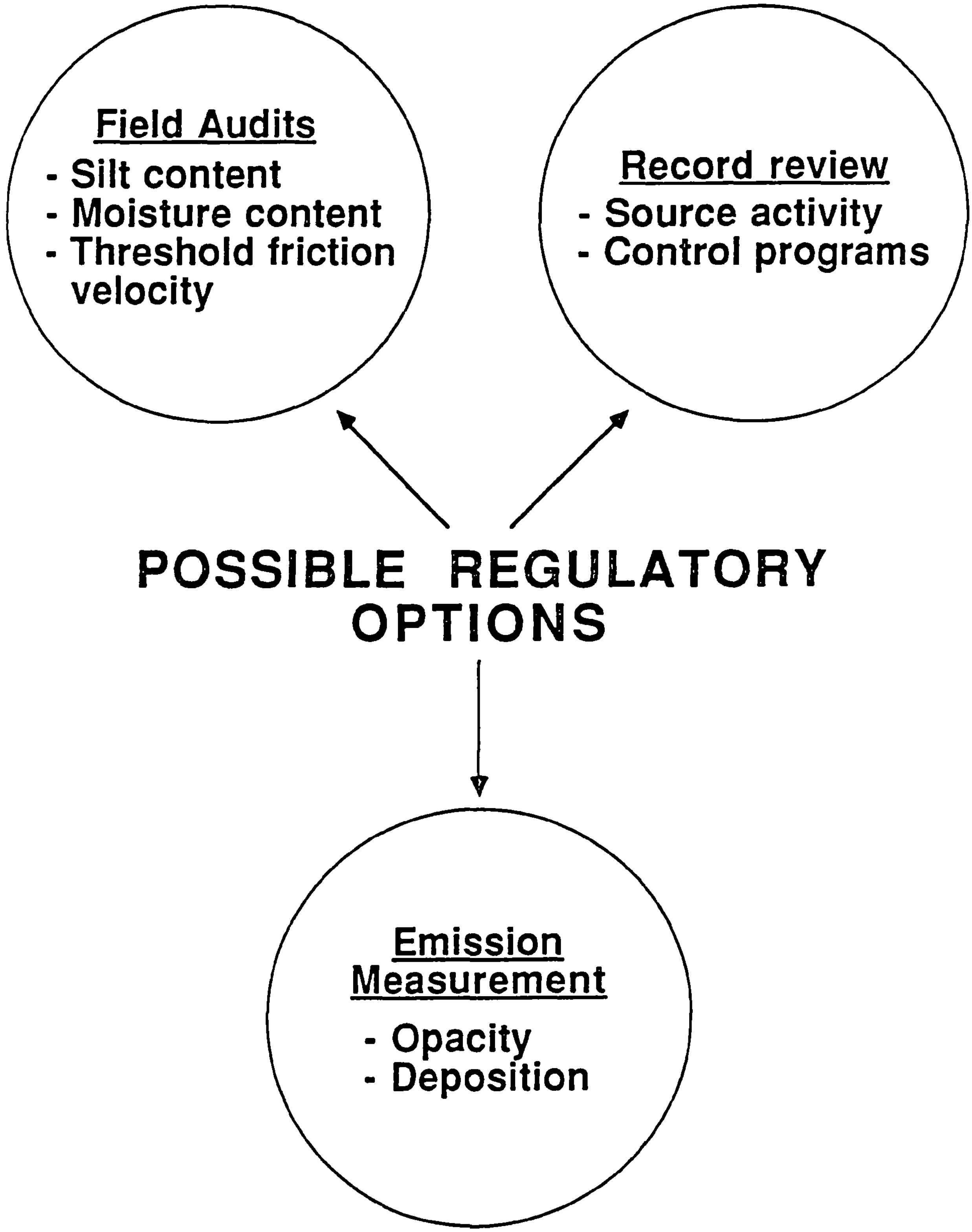
- No visible emission exceeding x% opacity
  (at the source)

COMPLIANCE TOOLS

Recordkeeping

Spot Inspections

Field Verification Techniques


Field Audits
- Silt content
- Moisture content
- Threshold friction velocity
Record review
- Source activity
- Control programs
POSSIBLE REGULATORY OPTIONS
Emission Measurement
- Opacity
- Deposition

PAVED ROADS

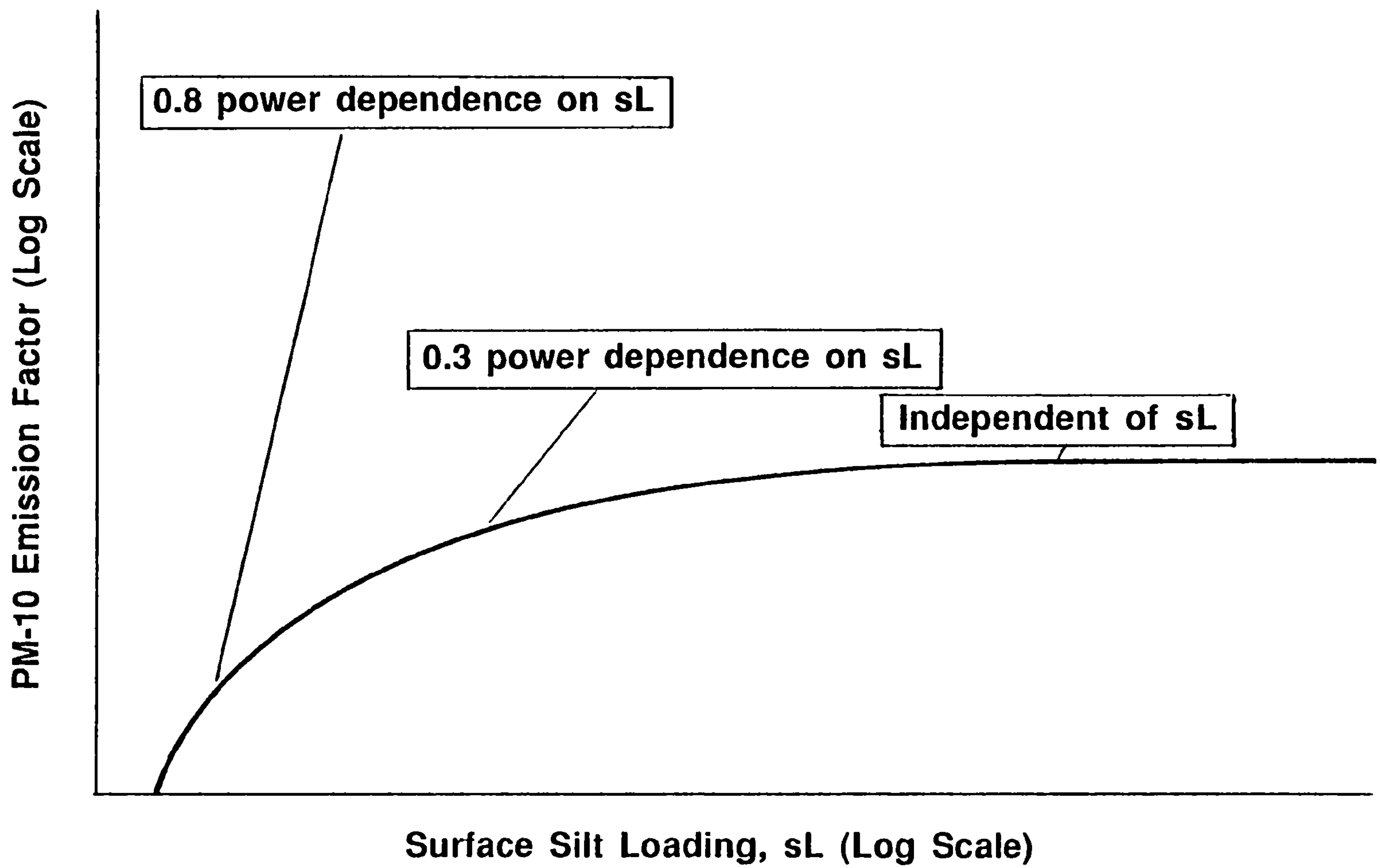
(Section 2.0)

PAVED ROADS

PM10 emissions characterized by "SILT LOADING," which is the mass of material $\leq$ 200 mesh (74 μmP) per unit area of travel lanes.

Measured silt loadings ranged over 4 orders of magnitude.

Emissions also depend, to a lesser extent, on weight of vehicles using the road.


0.8 power dependence on sL
0.3 power dependence on sL
Independent of sL
PM-10 Emission Factor (Log Scale)
Surface Silt Loading, sL (Log Scale)

SOURCES OF LOADINGS ON PAVED ROADS

- Sanding/salting
- Spills from haul trucks
- Carryout from unpaved areas
- Entrainment from unpaved adjacent areas
- Erosion from storm water
- Wind erosion from adjacent areas

PM10 EMISSION FACTOR FOR URBAN PAVED ROADS

$$e = 2.28\ (sL/0.5)^{0.8}\ (g/VKT)$$

$$e = 0.0081\ (sL/0.7)^{0.8}\ (lb/VMT) \qquad (2\text{-}1)$$

where:

e = PM10 emission factor, in units shown above

s = surface silt content, fraction of material smaller than 75 μm in diameter

L = total surface dust loading, g/m^2 ($grains/ft^2$)

VKT = vehicle kilometers traveled

VMT = vehicle miles traveled

$$sL = 21.3/V^{0.41}$$

where: sL = surface silt loading (g/m^2)

V = vehicles/day

PM10 EMISSION FACTOR FOR INDUSTRIAL PAVED ROADS

$$e = 220\ (sL/12)^{0.3} \quad (g/VKT) \qquad (2\text{-}3)$$

$$e = 0.77\ (sL/0.35)^{0.3} \quad (lb/VMT) \qquad (2\text{-}3)$$

where:

e = PM10 emission factor, in units shown above

s = surface silt content, fraction of material smaller than 75 μm in diameter

L = total surface dust loading, g/m^2 (oz/yd^2)

VKT = vehicle kilometers traveled

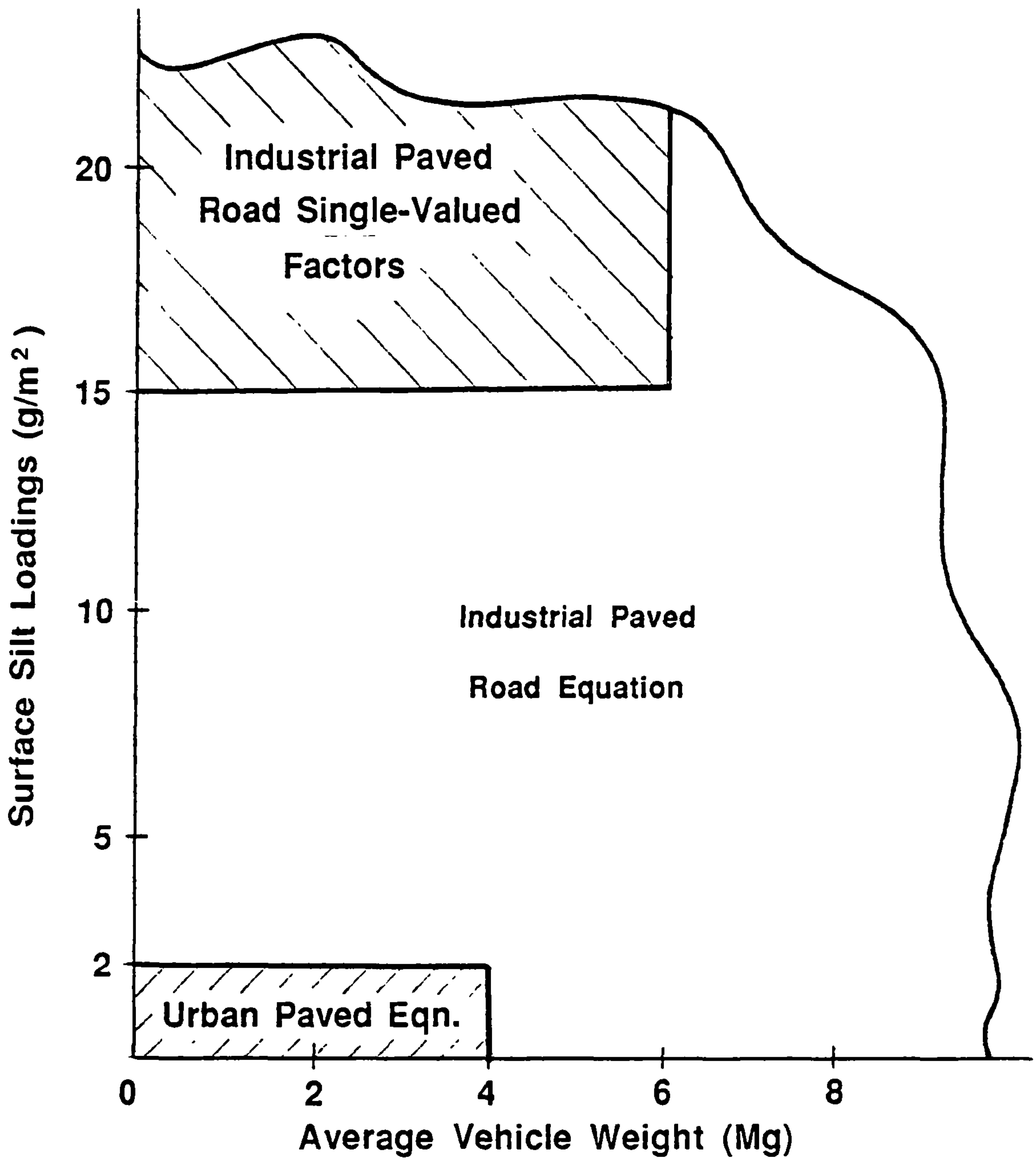
VMT = vehicle miles traveled

PM10 EMISSION FACTOR FOR HEAVILY LOADED INDUSTRIAL PAVED ROADS

$$e = 93 \quad \text{(g/VKT)} \qquad (2\text{-}4)$$

$$e = 0.33 \quad \text{(lb/VMT)} \qquad (2\text{-}4)$$

USE OF PAVED ROAD EMISSION FACTOR MODELS

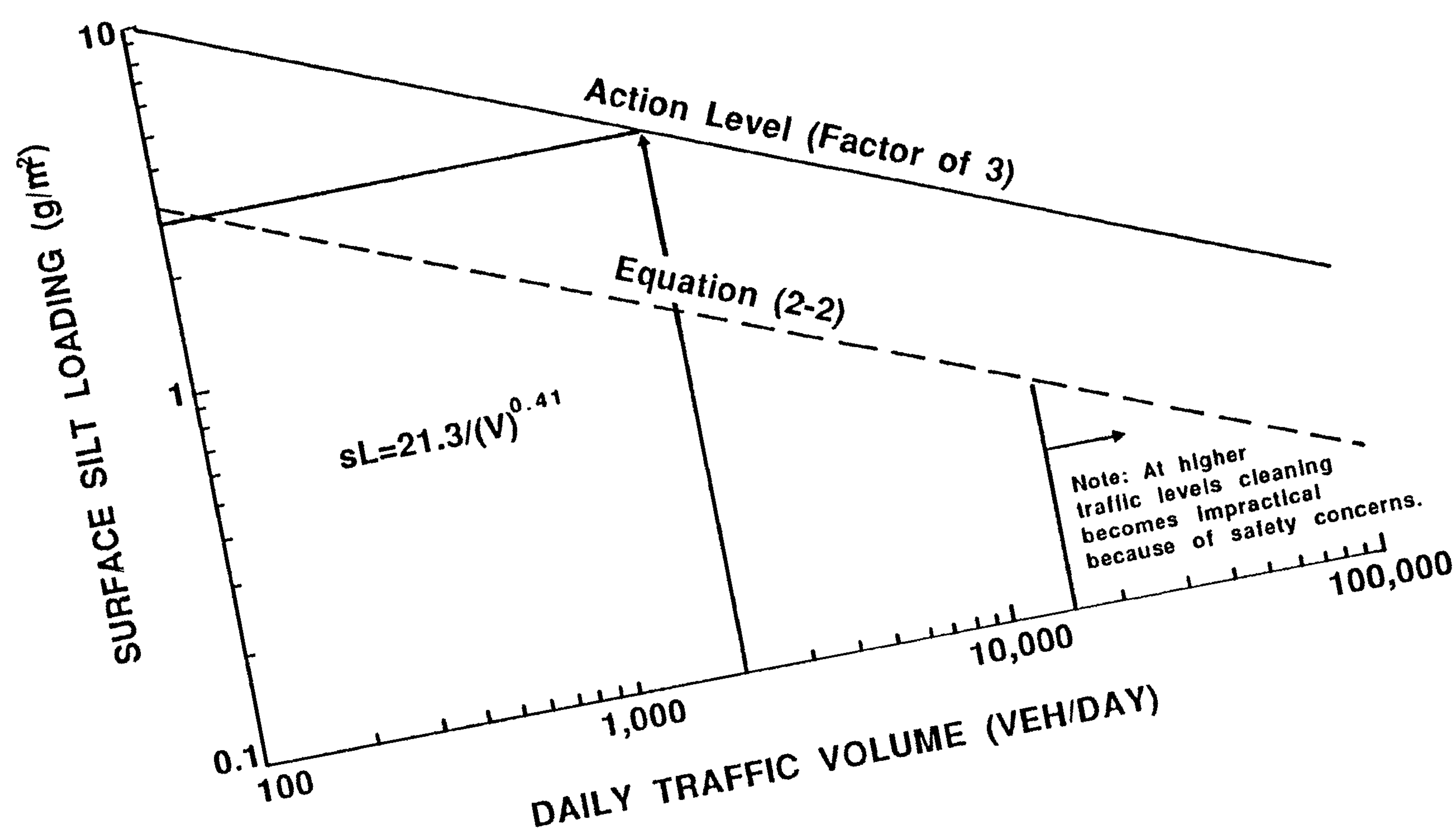


CONTROL OF PAVED ROAD EMISSIONS

Control programs either prevent material from being deposited onto travel surface or remove that which has been deposited.

EXAMPLE CONTROLS

PREVENTIVE	MITIGATIVE
Curbing	Vacuum sweeping
Improved snow/ ice traction materials	Water flushing
Truck cover requirements	Rapid clean-up of spills, etc.



10
1
0.1
SURFACE SILT LOADING (g/m²)
Action Level (Factor of 3)
Equation (2-2)
sL=21.3/(V)^0.41
Note: At higher traffic levels cleaning becomes impractical because of safety concerns.
100
1,000
10,000
100,000
DAILY TRAFFIC VOLUME (VEH/DAY)

UNPAVED ROADS

(Section 3.0)

UNPAVED ROADS

Historically, unpaved travel surfaces have accounted for the greatest portion of open dust emissions in industrial settings.

During 1970's, ~70% of non-process TSP emissions in iron and steel industry attributed to unpaved travel.

Numerous field programs during early 1980's to evaluate control techniques.

Numerous reasons for leaving roads unpaved

- length/traffic volume

- heavy industrial vehicles

- spillage in industrial settings

AP-42 UNPAVED ROAD PM10 EMISSION FACTOR EQUATION

$$E = 0.61 \left(\frac{s}{12}\right) \left(\frac{S}{48}\right) \left(\frac{W}{2.7}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \frac{(365-p)}{365} \text{ (kg/VKT)}$$

(3-1)

$$E = 2.1 \left(\frac{s}{12}\right) \left(\frac{S}{30}\right) \left(\frac{W}{3}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \frac{(365-p)}{365} \text{ (lb/VMT)}$$

where: E = PM_{10} emission factor in units stated

s = silt content of road surface material, percent

S = mean vehicle speed, km/h (mi/h)

W = mean vehicle weight, Mg (ton)

w = mean number of wheels (dimensionless)

p = number of days with $\geq$0.254 mm (0.01 in.) of precipitation per year

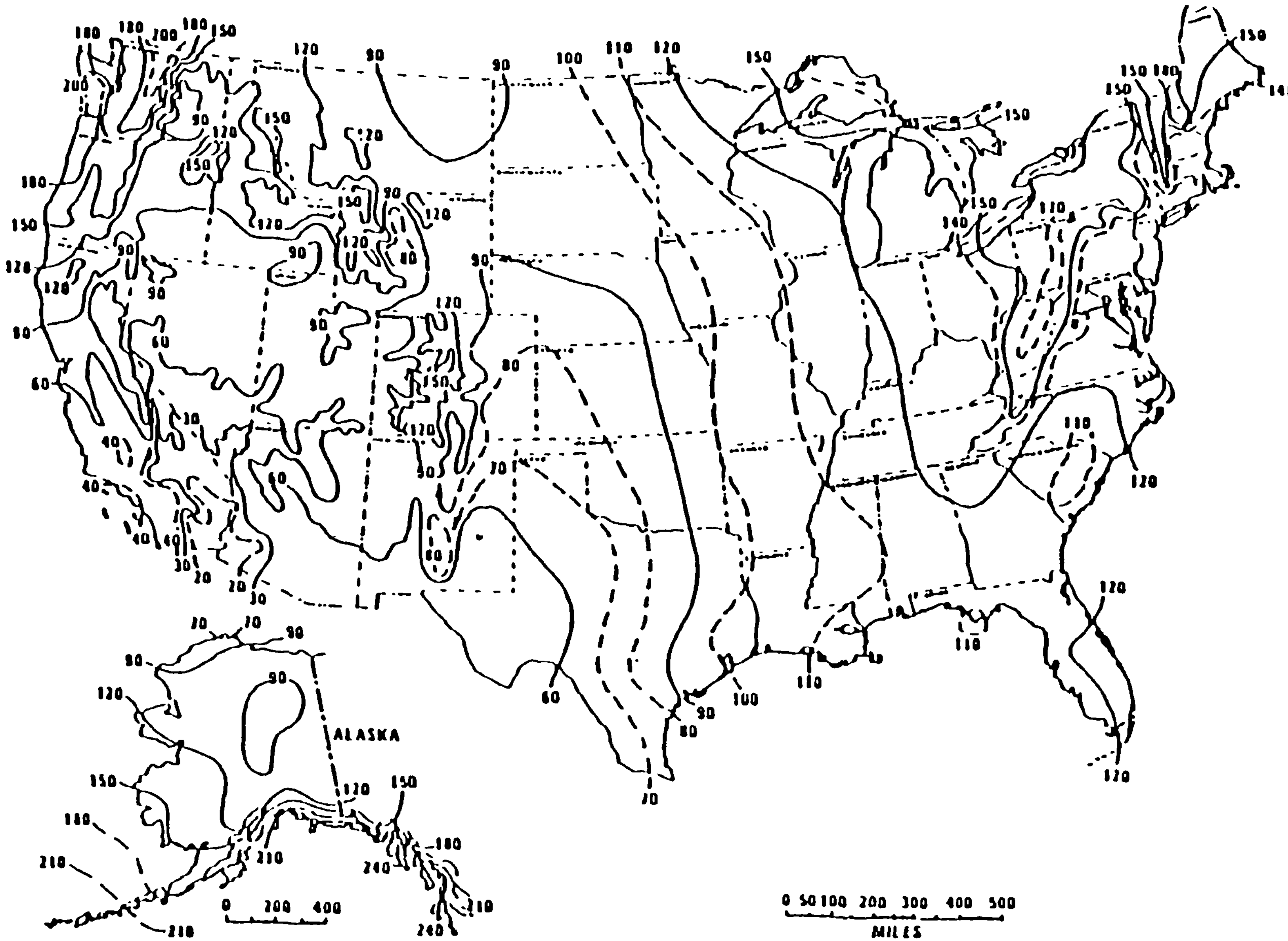


FIGURE 3-1. MEAN ANNUAL NUMBER OF DAYS WITH AT LEAST 0.01 IN OF PRECIPITATION[2]

TABLE 3-2.
CONTROL TECHNIQUES FOR UNPAVED SURFACES[a]

Source extent reduction:	Speed reduction Traffic reduction
Source improvement:	Paving Gravel surface
Surface treatment:	Watering Chemical stabilization[b] - Asphalt emulsions - Petroleum resins - Acrylic cements - Other

[a]Table entries reflect EPA draft guidance on urban fugitive dust control.
[b]See Table 3-3.

SURFACE TREATMENTS

Wet Suppression

- Watering
- Salts and other hygroscopic materials

Chemical Stabilization

- Petroleum resins
- Asphalt emulsions
- Adhesives

EMPIRICAL MODEL FOR WATERING AS A CONTROL TECHNIQUE

$$C = 100 - \frac{0.8\ p\ d\ t}{i} \qquad (3\text{-}2)$$

where:

C = average control efficiency (percent)

p = potential average hourly daytime evaporation rate (mm/hr)

d = average hourly daytime traffic rate (hr^{-1})

i = application intensity (L/m^2)

t = time between applications (hr)

p = 0.0049 mm/hr (value in Figure 3-2)

0.0065 " "

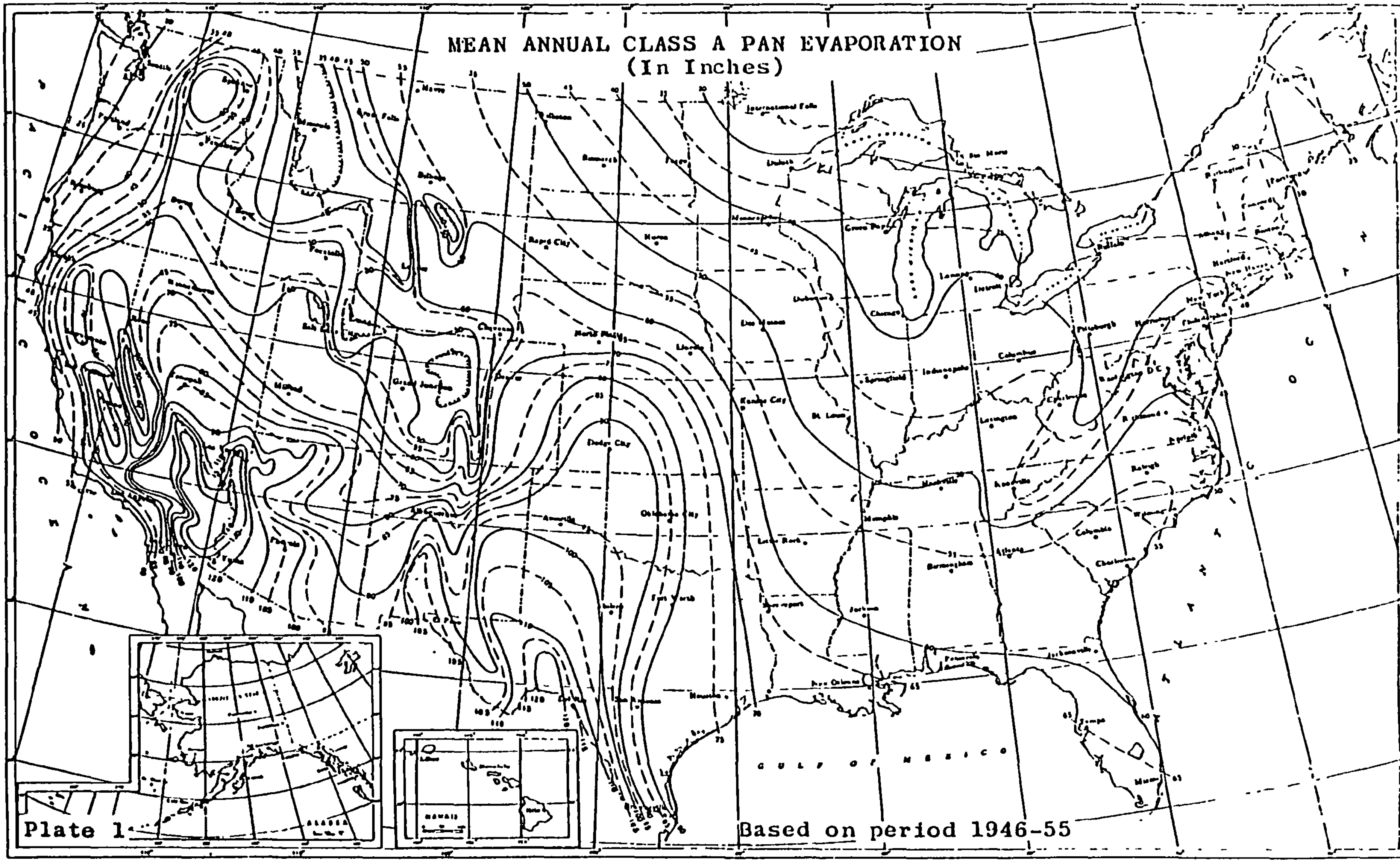
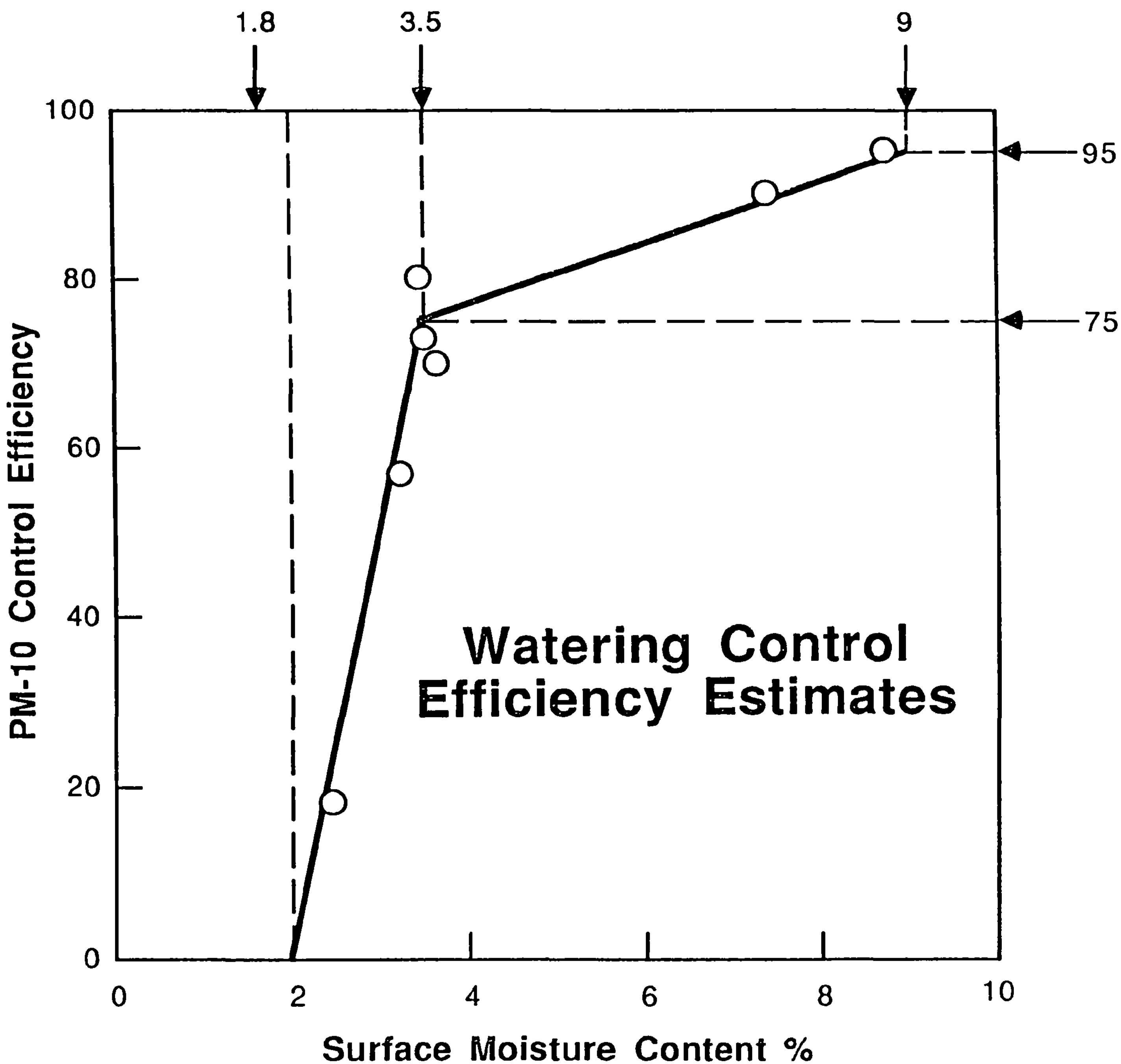


FIGURE 3.2 ANNUAL EVAPORATION DATA.[2]



1.8
3.5
9
100
80
60
40
20
0
95
75
PM-10 Control Efficiency
Watering Control Efficiency Estimates
0
2
4
6
8
10
Surface Moisture Content %

CHEMICAL STABILIZATION

Key Application Parameters

- APPLICATION FREQUENCY
- APPLICATION INTENSITY
- DILUTION RATIO

These three parameters may be combined into a single measure of the treatment history.

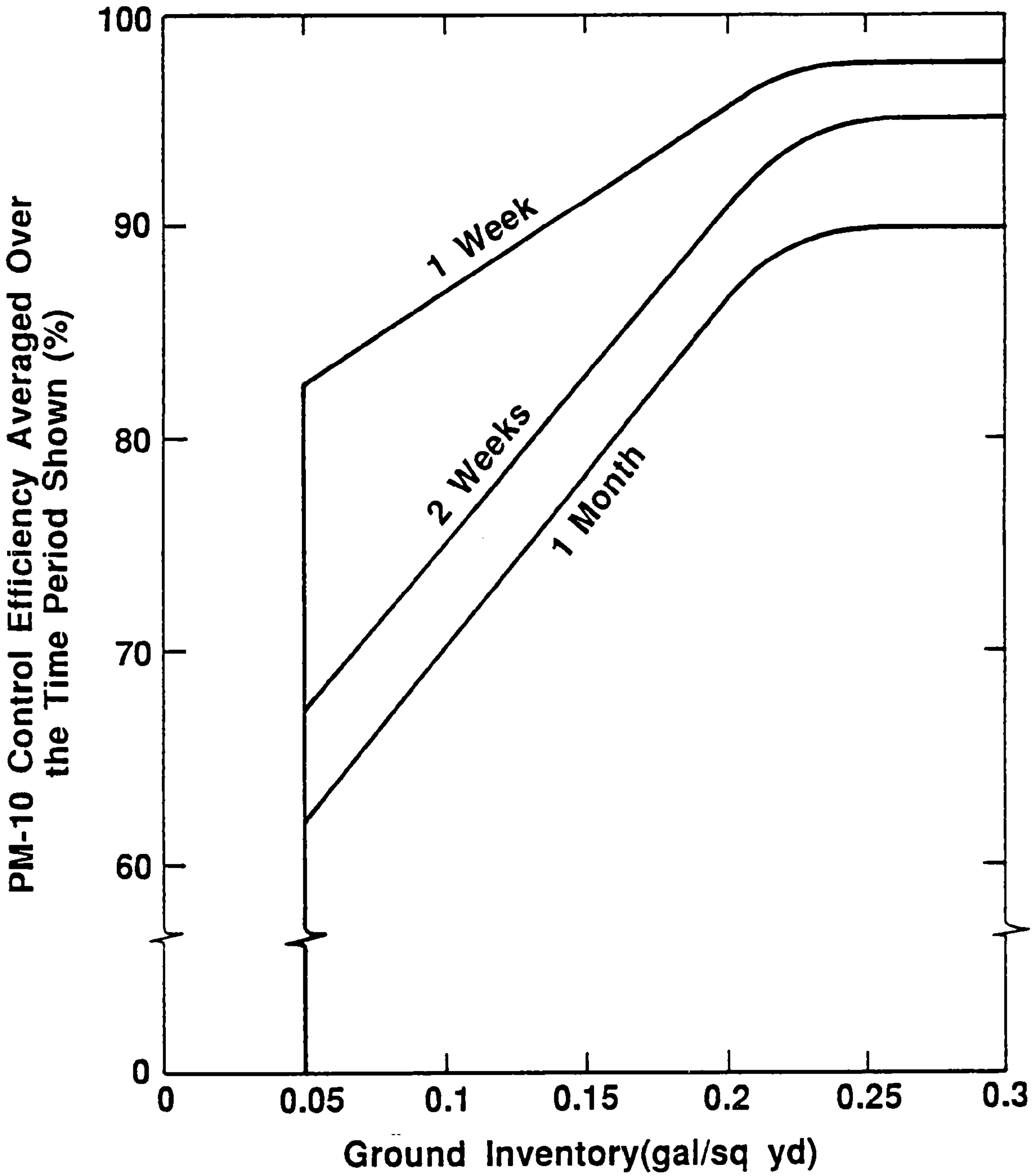
GROUND INVENTORY

Ground inventory is a measure of residual effects of earlier applications, and is found by adding together total volume per unit area of concentrate (not solution) since start of dust control season.

EXAMPLE

	Intensity (gal/yd^2)	Dilution Ratio	Ground Inventory (gal/yd^2)
May 1	0.25	1 part: 5 parts water	0.042
June 1	"	"	0.083
July 1	"	"	0.12
August 1	"	"	0.17
September	"	"	0.21

Chemical Dust Suppressant Control Efficiency Model



NOTES ON FIGURE 3-4

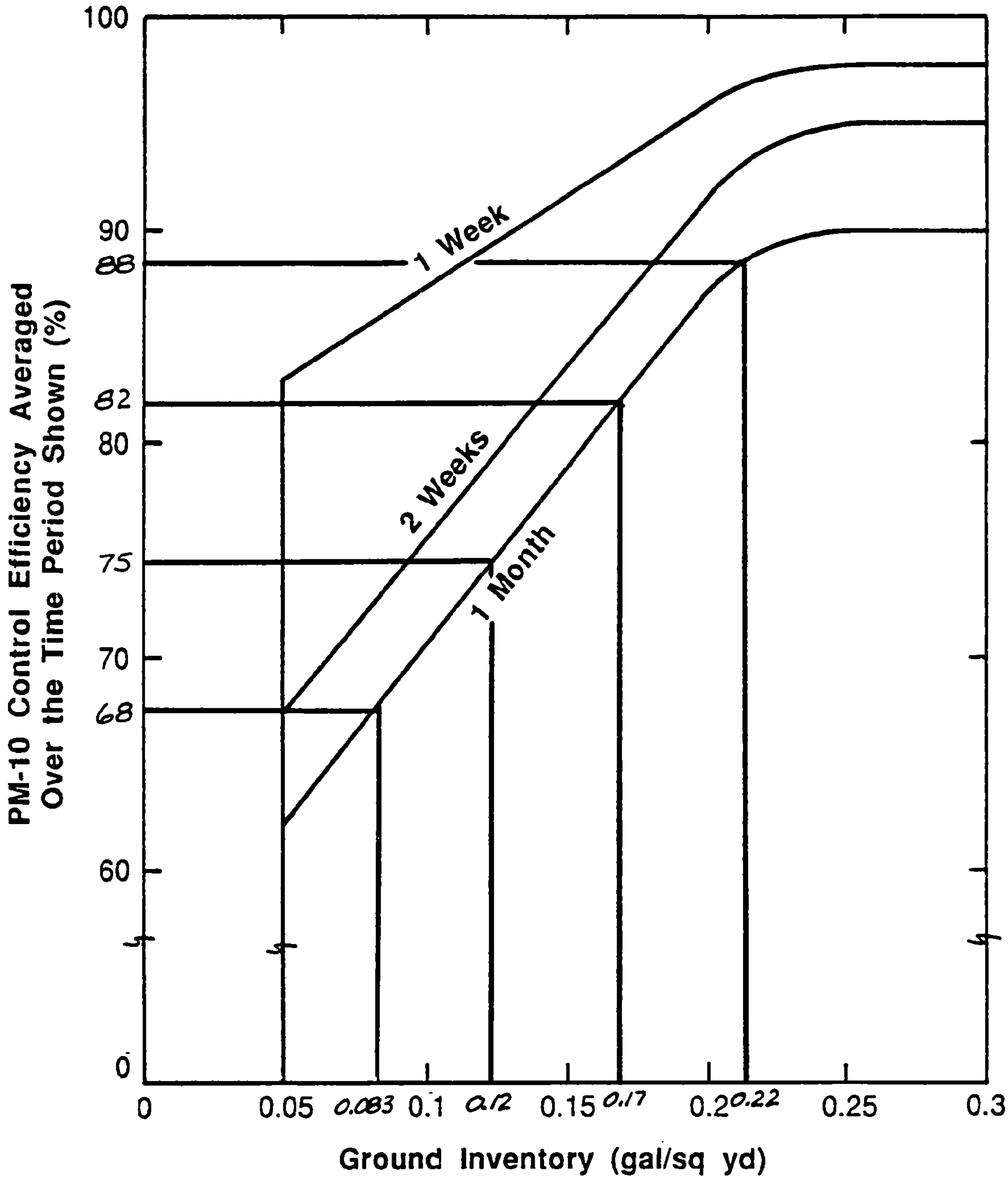
<u>No</u> credit for G.I. < 0.05 gal/yd^2

3 averaging periods shown represent common practice in iron and steel industry

Methodology based on model for <u>petroleum resins</u>; Figure itself represents an average for

- commercially available petroleum resin
- "generic" petroleum resin
- acrylic cement
- asphalt emulsion

CHEMICAL DUST SUPPRESSANT CONTROL EFFICIENCY MODEL



Averaging Period	Ground Inventory (gal/yd^2)	Average PM10 Control Efficiency %
May	0.042	0
June	0.083	68
July	0.12	75
August	0.17	82
September	0.21	88

Average control, May through September: 63%

STORAGE PILES

(SECTION 4.0)

PREDICTIVE EMISSION FACTOR EQUATION

$$E = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\ \text{(kg/Mg)}$$

$$E = k(0.0032)\frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\ \text{(lb/ton)}$$

Where:

E = emission factor

k = particle size multiplier (dimensionless)

U = mean wind speed, m/s (mph)

M = material surface moisture content (%)

Aerodynamic Particle Size Multiplier (k)					
< 50μm	< 30μm	< 15μm	< 10μm	< 5μm	< 2.5μm
1.0	0.74	0.48	0.35	0.20	0.11

COMPLICATING FACTORS FOR WIND EROSION

Limited availability of erodible material

Dominance of short-term wind gusts

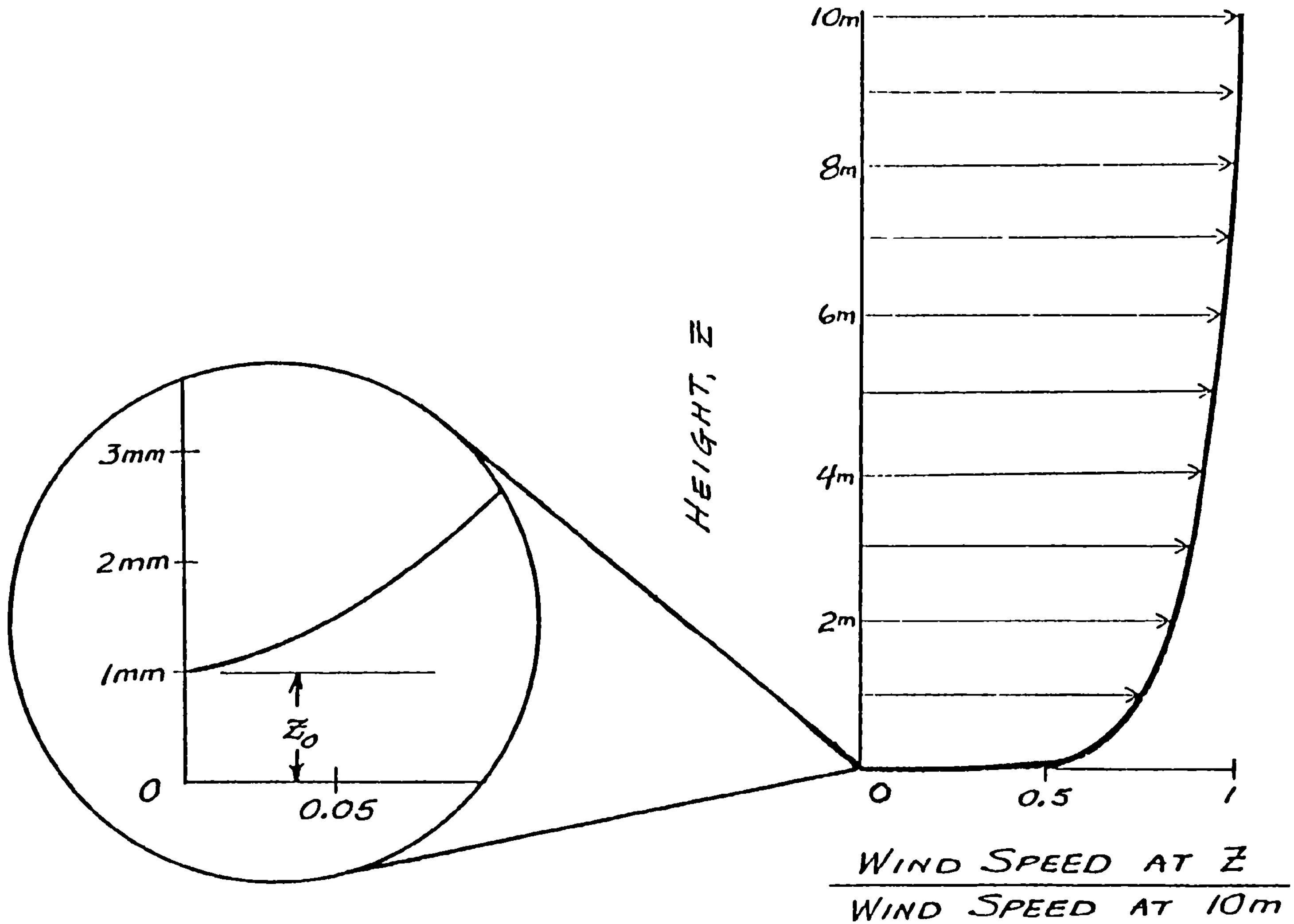
Non-uniformity of pile exposure to wind

LOGARITHMIC WIND VELOCITY PROFILE

$$u(z) = \frac{u^*}{0.4} \ln \frac{z}{z_o} \qquad (z > z_o)$$

where
- u = wind speed, cm/sec
- u^* = friction velocity, cm/sec
- z = height above test surface, cm
- z_o = roughness height, cm
- 0.4 = von Karman's constant, dimensionless

LOGARITHMIC WIND VELOCITY PROFILE



PREDICTIVE EMISSION FACTOR

$$\text{Emission factor} = k \sum_{i=1}^{N} P_i \quad g/m^2\text{-yr}$$

where k = particle size multiplier
N = number of disturbances per year
P_i = erosion potential corresponding to the observed (or probable) fastest mile of wind for the ith period between disturbances, g/m^2

AERODYNAMIC PARTICLE SIZE MULTIPLIERS

< 30 µm	< 15 µm	< 10 µm	< 2.5 µm
1.0	0.6	0.5	0.2

EROSION POTENTIAL FUNCTION

$$P = 58\,(u^* - u_t^*)^2 + 25\,(u^* - u_t^*) \quad g/m^2$$

$$P = 0 \text{ for } u^* \leqq u_t^*$$

where u^* = friction velocity (m/s)
u_t^* = threshold friction velocity (m/s)

TABLE 4-3. THRESHOLD FRICTION VELOCITIES--INDUSTRIAL AGGREGATES

Material	Threshold friction velocity, m/s	Roughness height, cm	Threshold wind velocity at 10 m (m/s)		Ref.
			z_o = actual	z_o = 0.5 cm	
Overburden[a]	1.02	0.3	21	19	7
Scoria (roadbed material)[a]	1.33	0.3	27	25	7
Ground coal[a] (surrounding coal pile)	0.55	0.01	16	10	7
Uncrusted coal pile[a]	1.12	0.3	23	21	7
Scraper tracks on coal pile[a,b]	0.62	0.06	15	12	7
Fine coal dust on concrete pad[c]	0.54	0.2	11	10	12

[a]Western surface coal mine.
[b]Lightly crusted.
[c]Eastern power plant.

CONTOURS OF NORMALIZED SURFACE WIND SPEEDS, U_s/U_r

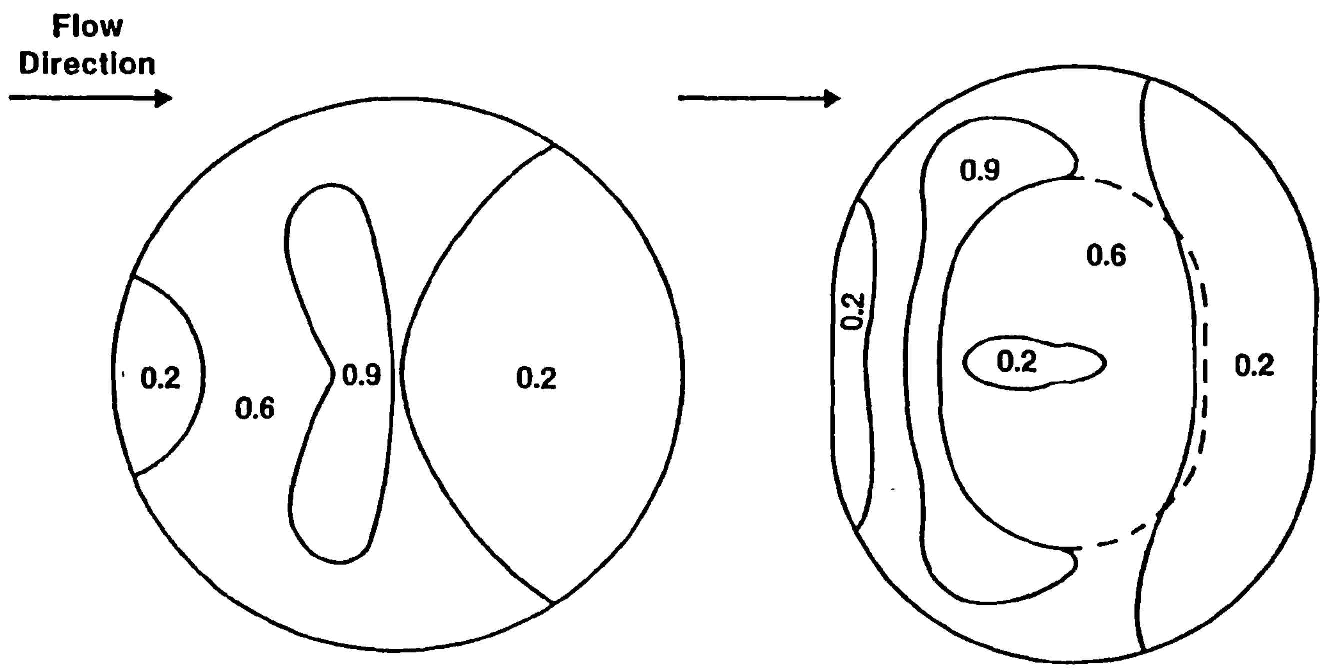


TABLE 4-6. CONTROL TECHNIQUES FOR STORAGE PILES

Material handling	
Source extent reduction	Mass transfer reduction
Source improvement	Drop height reduction Wind sheltering Moisture retention
Surface treatment	Wet suppression
Wind erosion	
Source extent reduction	Disturbed area reduction Disturbance frequency reduction Spillage cleanup
Source improvement	Spillage reduction Disturbed area exposure (wind) reduction
Surface treatment	Wet suppression Chemical stabilization

CONSTRUCTION/DEMOLITION

(Section 5.0)

DEMOLITION OF STRUCTURES

Mechnical or explosive
dismemberment

Debris loading

On-site truck traffic

ROAD AND BUILDING CONSTRUCTION

- Topsoil removal
- Earth moving
  (cut & fill operations)
- Truck haulage

CONSTRUCTION PM-10 EMISSION FACTORS

- Topsoil removal: 5.7 kg/VKT for pan scrapers
- Earthmoving: 1.2 kg/VKT for pan scrapers
- Truck haulage: 2.8 kg/VKT for haul trucks
- Bulldozing: 0.45 kg/hour

DEMOLITION PM-10 EMISSION FACTORS*

Dismemberment:	$e_D = 0.25\ g/m^2$
Debris Loading:	$e_L = 4.6\ g/m^2$
Truck Traffic:	$e_T = 52\ g/m^2$
Total:	$57\ g/m^2$

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* In terms of mass per unit floor space demolished. All values are based on predictive emission factor equations with default inputs.

CONSTRUCTION/DEMOLITION DUST CONTROL PROGRAMS

Watering or chemical treatment of travel surfaces*

Wet suppression or shielding of materials stored and handled**

Work practice modifications

- Paving and cleaning access points
- Paving roads earlier in construction process
- Truck washes, grizzlies at access points

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* Identical to earlier discussion on unpaved roads.

** Identical to earlier discussion on storage piles.

APPROPRIATE MEASURES FOR COMPLIANCE DETERMINATION

- Permits
- Field audits
- Work practices (recordkeeping)
- Emission measurement